Inhibitory control and lexical alignment in children with an autism spectrum disorder

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Running head: Inhibitory control and lexical alignment in autism

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Background: Two experiments investigated the contribution of conflict inhibition to pragmatic deficits in children with autism spectrum disorder (ASD). Typical adults' tendency to re-use interlocutors' referential choices (lexical alignment) implicates communicative perspective-taking, which is regulated by conflict inhibition. We examined whether children with ASD spontaneously lexically aligned, and whether conflict inhibition mediated alignment.

Methods: Children with ASD and chronological- and verbal-age-matched typically-developing controls played a picture-naming game. We manipulated whether the experimenter used a preferred or dispreferred name for each picture, and examined whether children subsequently used the same name.

Results: Children with ASD spontaneously lexically aligned, to the same extent as typically-developing controls. Alignment was unrelated to conflict inhibition in both groups.

Conclusions: Children with ASD's referential communication is robust to impairments in conflict inhibition under some circumstances. Their pragmatic deficits may be mitigated in a highly structured interaction.

Key words: autism spectrum disorder; alignment; inhibitory control; perspective-taking

Conversational partners use not only linguistic skills (e.g., grammatical knowledge), but also pragmatic skills (e.g., turn-taking), to communicate effectively. Pragmatic deficits – difficulties with social language use – are associated with impaired communication in ASD (Volden, 2002). One prominent account attributes these deficits to impaired understanding of others' mental states (theory of mind; Baron-Cohen, Leslie, & Frith, 1985). Newer research links pragmatic processing with executive functioning (cf., Nilsen & Fecica, 2011) in ASD. We consider the relationship between pragmatic language and executive functioning in children with ASD, exploring the extent to which conflict inhibition mediates one aspect of referential communication, *lexical alignment*.

When conversing, people must choose between alternative ways of referring to entities, (e.g., *rabbit, bunny, animal, it*). Speakers' referential choices (*names*) are important:. Communication can stall if speakers use a name their conversational partner misunderstands. One important determinant of referential choice is lexical alignment (or entrainment): the tendency for speakers to converge on the same names for particular entities. For example, after one partner refers to a *bunny*, their partner will tend to refer to a *bunny* rather than a *rabbit.* Lexical alignment is robust, pervasive, and implicit in typical dialogue (Garrod & Anderson, 1987). Importantly, higher levels of alignment promote effective and satisfying communication (Fusaroli et al., 2012; Reitter & Moore, 2014).

One view is that alignment arises from priming mechanisms (Pickering & Garrod, 2004): speakers converge on names used by their partners because their partners' prior use primes particular lexical representations. Pickering and Garrod (2004) argued that priming-based alignment automatically gives rise to shared semantic representations, so that interlocutors may not need to use theory of mind, or infer common ground, to achieve mutual understanding.

Another view is that alignment – particularly lexical alignment - is a manifestation of *audience design*, whereby speakers design utterances to facilitate hearers' likely understanding (Clark & Marshall, 1981). This has been demonstrated extensively in typical adult dialogue (see Clark, 1992), and even in young typically-developing children (e.g., Nadig & Sedivy, 2002). Audience design requires perspective-taking, thereby implicating theory of mind: speakers must understand that their mental states may differ from their hearers', and must accommodate those differences in their utterances.

Within an audience design framework, lexical alignment can be interpreted as a type of communicative perspective-taking; speakers use shared linguistic context – what they and their partner have previously said – to infer what their partner will understand. A partner's previous choices provide relevant evidence: If he uses a particular name for an object, it indicates he understands and prefers that name (and associated conceptualization; Clark, 1997). By using the same name, the speaker maximises the likelihood of mutual understanding, and hence successful communication. Conversely, using a different name (i.e., failing to align) implies reference to a different object, potentially causing miscommunication (Metzing & Brennan, 2003). Accordingly, Branigan, Pickering, Pearson, McLean, and Brown (2011) showed that when naming objects, people overrode their preferred name to use a normally dispreferred name that their partner previously used; this tendency was enhanced when conversing with a partner who appeared less capable (and hence at risk of misunderstanding).

Communicative perspective-taking has been linked to conflict inhibition, a component of executive functioning, in both adults' and children's dialogue. Conflict inhibition is the domain-general ability to control interference, through suppressing a salient response and generating a novel response. Typical children and adults with greater conflict inhibition are better able to accommodate another's visual perspective during interaction (Nilsen & Graham, 2009; Wardlow, 2013). This benefit could extend to accommodating shared linguistic context (hence lexical alignment).

Verbal children with ASD show reduced sensitivity to audience and social context in production and comprehension of conversational speech (e.g., Capps, Kehres, & Sigman, 1998). This has been attributed to theory of mind impairments, held to frustrate perspective-taking. However, the relation between pragmatic deficits and impaired theory of mind is unclear. Training mental state understanding does not improve children with ASD's conversational skills (Hadwin, Baron-Cohen, Howlin, & Hill, 1997). Conversely, training their communication skills does not improve their mental state understanding (Chin & Bernard-Opitz, 2000). Moreover, studies find no consistent relationship between children with ASD's theory of mind and their use of communicative perspective-taking (Capps et al., 1998; DeMarchena & Eigsti, 2015; Nadig, Vivanti, & Ozonoff, 2009; Dahlgren & Sandberg, 2008).

Accordingly, Nilsen and Fecica (2011) proposed a more nuanced account of children with ASD's pragmatic deficits, emphasizing the online processing demands of communicative perspective-taking. Specifically, they posited that conflict inhibition supports the use of mental state information in conversation. Their account draws on research ascribing ASD symptomatology to executive functioning deficits, including conflict inhibition (e.g., Russell, 1997). They theorized that impaired conflict inhibition might limit communicative perspective-taking, even among children with ASD who pass theory of mind tasks (e.g., false belief tasks; Baron-Cohen et al., 1985).

These accounts make conflicting predictions concerning lexical alignment in children with ASD and typically-developing children. If communicative perspective-taking is determined purely by theory of mind, we would expect a relationship between lexical alignment and theory of mind, such that children with ASD who have impaired theory of mind would be less likely to align, and children with ASD would show less alignment as a group than typically-developing children. However, available evidence does not favour this account. In the only published study examining children with ASD's lexical alignment (Branigan, Tosi, and Gillespie-Smith, 2016), a child and experimenter took turns naming pictures in a picture-matching game. Children with ASD showed spontaneous lexical alignment, using the same name for a picture previously used by the experimenter, and aligned to the same extent as chronological-age-matched and verbal-age-matched typically-developing children. Importantly, lexical alignment was not related to theory of mind in children with ASD, who underperformed typically-developing children on a false belief task. Branigan et al. (2016) suggested that lexical alignment in both groups arose from automatic priming mechanisms, but noted that their results could not exclude different mechanisms underlying alignment in ASD versus typically-developing groups (e.g., audience design).

If communicative perspective-taking is mediated by conflict inhibition, however, we might expect a relationship between children with ASD's tendency to align and their conflict inhibition, independent of theory of mind; this would also hold for typically-developing children. Moreover, to the extent that children with ASD exhibited poorer conflict inhibition than typically-developing children, we would also expect group differences in alignment, potentially implicating conflict inhibition in other aspects of children with ASD's pragmatic language impairment. We tested these predictions by investigating whether conflict inhibition mediated lexical alignment in two samples of children with ASD. We predicted that children with ASD with poorer conflict inhibition would struggle to engage communicative perspective-taking in conversation, and thus display a reduced tendency to lexically align that could compromise successful communication.

We used Branigan et al.'s (2016) picture-naming paradigm. In two experiments, we manipulated whether the experimenter used a preferred or dispreferred name for each picture (e.g., *rabbit* vs. *bunny*), and measured whether the child used the same or an alternative name to subsequently refer to the same picture. Each picture presented an opportunity for children to engage in communicative perspective-taking, by naming their target card for the experimenter.

We also measured children's conflict inhibition, using two different tasks. We examined whether children with ASD showed spontaneous lexical alignment on preferred and dispreferred names; whether they showed reduced lexical alignment compared to chronological-age-matched and verbal -age-matched typically-developing children; and whether conflict inhibition mediated individual differences in lexical alignment.[1]

EXPERIMENT 1

Method

Participants

Participants were 12 children with ASD (10 male) attending a special school in West Sussex, UK, whose clinical diagnoses we corroborated with the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). All SCQ scores were above the recommended cut-off of 15 (mean 23.7; range 16-29; Wiggins, Bakeman, Adamson, & Robins, 2007).

We tested language ability using the British Picture Vocabulary Scale (BPVS-3; Dunn, Dunn, & Styles, 2009). We matched each child with ASD individually to one typically-developing chronological-age-matched child and one typically-developing verbal-age-matched child (using raw BPVS scores; Table 1). Control children attended a mainstream primary school in Dorset, UK.

Caregivers provided written consent; children gave verbal assent. The Cross-School Research Ethics Committee (C-REC) for Sciences and Technology, University of Sussex, UK, approved the study.

Materials and Procedure

Children were tested individually in a one-hour session, in a fixed order: BPVS-3 → picture-naming game → theory of mind task → conflict inhibition task.

BPVS-3: Children selected which picture from four represented a word's meaning.

Picture-naming game: The materials, design and procedure were identical to Branigan et al. (2016). The 20 experimental items comprised pairs of pictures (a *prime* and *target*), each depicting an object with two acceptable names (e.g., *rabbit* and *bunny*), and a scripted *prime name* (*preferred* vs. *dispreferred*); they were developed by Branigan et al. on the basis of two pre-tests involving different groups of typically-developing children. In the first pretest, 18 children spontaneously named a set of pictures; pictures for which one name ('preferred') was produced at least twice as frequently as an alternative name ('dispreferred') were selected. In the second, >70% of 12 children selected an appropriate picture from four (including a semantically-related distractor) when given the dispreferred name.

There were two pairs (Experimenter/Participant) of lists, each containing one version of each experimental item in a Latin Square design, plus 28 filler pictures. Participants were randomly assigned to lists; item order was individually randomized with constraints that two fillers intervened between each prime and target, and the eight 'snap' trials (involving identical experimenter/child pictures) were distributed through the game.

The experimenter and child each had a pile of cards, and alternated turning over their top card, naming it, and laying it face-up on the table. When adjacent cards were identical, the first player to say 'Snap!' won the cards. The experimenter always named her prime card first, using the preferred or dispreferred name following her script; after two intervening fillers, the child named his target card, which displayed the same picture as the preceding prime card (Figure 1).

Theory of mind task: Tager-Flusberg and Sullivan's (1994) 'birthday puppy' story measures second-order false belief understanding. A cartoon video showed a mother deceiving her son about a gift. To pass, children had to correctly identify what the mother thought her son thought his gift was.

We examined second-order theory of mind because previous research did not support a correspondence between first-order theory of mind and conversation, and conversation could plausibly involve second-order theory of mind (i.e., what does my partner think/know about what I think/know). We also wished to avoid ceiling effects in first-order theory of mind tasks found in previous studies (e.g., Hopkins et al., 2016).

Conflict inhibition task: The junior Hayling task (Shallice et al., 2002) measures verbal interference control. In part A, children verbally completed 10 sentences with an expected word (e.g., *umbrella* after *If someone is walking in the rain, they usually carry an…*). Each correct response scored 1 point (optimal score: 10). In part B, children verbally completed 10 sentences with a word unrelated to those in the sentence (e.g., *If your neck is cold, you put on a…*), and to the expected completing word. Responses were scored for 'unrelatedness': expected word (*scarf*): 3 points; semantically-related word (e.g., *coat*): 1 point; unrelated word (e.g., *skateboard*): 0 points (optimal score = 0). Relevant for our study, Part B measures children's ability to inhibit semantically-constrained responses.

Results

Theory of mind and junior Hayling tasks

Fewer children with ASD (7/12) than typically-developing children (23/24) correctly answered the second-order false belief question, χ^2 (1) = 8.10, p = .004. Children with ASD underperformed typically-developing children in both parts of the junior Hayling (Part A: mean 7.50 vs. 8.92; Part B: mean 9.42 vs. 3.33; both ps < .01).

Picture-naming game (Table 2)

Target responses were coded as *Preferred, Dispreferred* or *Other*. We analysed game data with logit mixed effect (LME) models, using the lme4 package (version 1.1-12, Bates et al., 2016) in R (version 3.3.1; R Code Team, 2016). LME models simultaneously incorporate by-item and by-participant variation, and – unlike traditional analyses, such as ANOVA – are appropriate for categorical response variables. Unless stated, we included maximal by-item and by-participant random effect structures, permitting a more precise estimation of sources of variability (Barr et al., 2013).

Following Branigan et al. (2016), we report three sets of analyses. First, we examined whether children with ASD and whether typically-developing children aligned on a preferred name. Second, we examined whether children with ASD and whether typically-developing children aligned on a dispreferred name. These analyses examined whether lexical alignment occurred in children with ASD and in typically-developing children; they did not seek to compare alignment between children with ASD and typically-developing children. Consequently, we grouped the typically-developing children into a single group in these analyses, to give greater statistical power. These analyses also incorporated scores from part B of the junior Hayling as a fixed effect (i.e., predictor variable) to examine the relationship between alignment and conflict inhibition. Model convergence issues precluded including other individual difference measures (e.g., theory of mind); however, these were incorporated in separate analyses (see 'Combined Analyses').

Third, we compared whether children with ASD and typically-developing children differed in their overall tendency to align. In order to distinguish the potential effects of language exposure and language ability on children with ASD's tendency to align, we separated the typically-developing children into a chronological-age-matched group and a verbal-age-matched group. We compared each typically-developing group with the ASD group on their overall likelihood of aligning with the experimenter (i.e., likelihood of using the same name as the experimenter, whether preferred or dispreferred).

Likelihood of aligning on preferred names: ASD and typically-developing groups (Table 3)

Fixed effects were prime name and junior Hayling score. We coded preferred name responses as 1, and all others (dispreferred/other) as 0. The effect of prime name was significant for both groups: children with ASD and typically-developing children were more likely to produce a preferred name after hearing the experimenter use a preferred, rather than dispreferred, name. For both groups, junior Hayling score did not interact significantly with prime name, suggesting that alignment on preferred names was not mediated by conflict inhibition in children with ASD and typically-developing children.

Likelihood of aligning on dispreferred names: ASD and typically-developing groups (Table 4)

Fixed effects were prime name and junior Hayling score; dispreferred responses were coded as 1, and all others (preferred/other) as 0. There was a significant effect of prime name for both groups: children with ASD and typically-developing children were more likely to produce a dispreferred name after hearing a dispreferred, rather than preferred, name. For both groups, junior Hayling score did not interact significantly with prime name, suggesting that alignment on dispreferred names was not mediated by conflict inhibition in children with ASD and typically-developing children.

Likelihood of aligning on either name: ASD vs. typically-developing groups (Table 7)

Fixed effects were group, prime name, and a group:prime name interaction. The ASD group's likelihood of aligning on either name was treated as a model intercept against which the typically-developing groups were compared: if the chronological-age-matched or verbal-age-matched group had a different likelihood of aligning, compared to the ASD group, this would be reflected in a significant contrast coefficient for that group. The contrasts for the chronological-age-matched and verbal-age-matched groups were not significant: the ASD group's lexical alignment did not differ significantly from the chronological-age-matched and verbal-age-matched groups'.

Discussion

Children with ASD showed spontaneous lexical alignment in a picture-naming game, to the same extent as typically-developing chronological-age-matched and verbal-age-matched children. Critically, we found no evidence for a relationship between children with ASD's conflict inhibition and their tendency to align on either a preferred or a dispreferred name. Moreover, children with ASD significantly underperformed typically-developing children on part B of the junior Hayling, yet did not align significantly less.

However, the junior Hayling may not have adequately captured children with ASD's inhibitory ability. Children with ASD obtained significantly lower scores than controls on part A as well as part B of the junior Hayling, potentially reflecting deficits of generativity rather than inhibition (Hill & Bird, 2006). Furthermore, the idiosyncrasies of children with ASD's 'expected' responses on part A suggest they were less semantically constrained than typically-developing children in the task overall, possibly requiring less interference control to suppress what should have been highly salient responses.

We therefore replicated Experiment 1 with different children, and with a task which has reduced generativity demands (the day-night task; Gerstadt, Hong, & Diamond, 1994).

EXPERIMENT 2

Method

Participants

Participants were 14 children with ASD (8 male) attending special schools in West Sussex and London, UK, with SCQ scores ≥15 (mean score = 21.9; range = 15-31). Matching procedures were as in Experiment 1 (Table 1). Control children were recruited from personal contacts. Caregivers provided written consent; children gave verbal assent. Sussex University's C-REC (Sciences and Technology) approved the study.

Materials and procedure

Children were tested individually in a one-hour session, in a fixed order: BPVS-3 → picture-naming game → theory of mind task → day-night task.

Excluding the day-night task, tasks were as in Experiment 1.

Conflict inhibition task: The day-night task is a Stroop-like test of visual interference control. We followed Gerstadt et al.'s (1994) procedure. Children were shown two types of card: Blue depicting a moon and stars, and white depicting a sun. They were instructed to say *day* to moon cards, and *night* to sun cards. Children named 16 test items, comprising 8 sun and 8 moon cards, in a pseudo-random order. We coded responses as correct or incorrect, and calculated an accuracy score for each child.

Results

Theory of mind and day-night tasks

Fewer children with ASD (4/14) than typically-developing children (22/28) answered the second-order false belief question correctly (χ^2 (1) = 9.89, p = .002). However, the ASD and typically-developing groups performed equally well on the day-night task (mean = .89 vs. .91; t(40) = .62, p = .54).

Picture-naming game (Table 2)

The data were coded and analysed as in Experiment 1.

Likelihood of aligning on preferred names: ASD and typically-developing groups (Table 5)

Fixed effects were prime name and day-night score. Preferred responses were coded as 1, all others (dispreferred/other) as 0. There was a significant effect of prime name for both groups: children with ASD and typically-developing children were more likely to produce a preferred name after hearing a preferred, rather than dispreferred, name. For both groups, day-night score did not interact significantly with prime name, suggesting that alignment on preferred names was not mediated by conflict inhibition in children with ASD and typically-developing children.

Likelihood of aligning on dispreferred names: ASD and typically-developing groups (Table 6)

Fixed effects were prime name and day-night score. Dispreferred responses were coded as 1, all other responses (preferred/other) as 0. There was a significant effect of prime name for both groups: children with ASD and typically-developing children were more likely to produce a dispreferred name after hearing a dispreferred, rather than preferred, name. For both groups, day-night score did not interact significantly with prime name, suggesting that alignment on dispreferred names was not mediated by conflict inhibition in children with ASD and typically-developing children.

Likelihood of aligning on either name: ASD vs. typically-developing groups (Table 7)

Fixed effects were group, prime name, and a group:prime name interaction. Again, contrast coefficients for the chronological-age-matched and verbal-age-matched groups were not significant; children with ASD did not differ significantly from either chronological-age-matched or verbal-age-matched children in the extent to which they aligned.

Combined analyses

To increase confidence in our findings, we ran further analyses wherein the ASD and typically-developing groups from Experiments 1 and 2 were collapsed into a single ASD 'supergroup' (N=26) and a single typically-developing 'supergroup' (N=52), giving us greater statistical power.

Likelihood of aligning on preferred or dispreferred names: ASD supergroup (Table 8)

Fixed effects were prime name, theory of mind (correct vs. incorrect), verbal age, chronological age, and SCQ, plus interactions between prime name and all individual difference measures. Responses were coded as before. There was a significant effect of prime name on the likelihood of producing both preferred and dispreferred names: Children with ASD were more likely to produce a preferred name after a hearing a preferred rather than dispreferred name, and to produce a dispreferred name after hearing a dispreferred rather than preferred name. There were no significant interactions with prime name, suggesting that alignment on preferred and dispreferred names in children with ASD was not mediated by theory of mind, autism severity (i.e., SCQ), chronological age, or verbal age.

Likelihood of aligning on either preferred or dispreferred names: typically-developing supergroup (Table 9)

Fixed effects were prime name, theory of mind, verbal age, and chronological age, plus interactions of prime name with all individual difference measures. Responses were coded as before. There was a significant effect of prime name on the likelihood of producing both preferred and dispreferred names: Typically-developing children were more likely to produce a preferred name after a preferred name than a dispreferred name, and to produce a dispreferred name after a dispreferred name than a preferred name. There were no significant interactions with prime name in the dispreferred name analysis, suggesting that alignment on dispreferred names was not mediated by theory of mind, chronological age, or verbal age.

There was a marginally significant main effect of verbal age, and a marginally significant prime name:verbal interaction in the preferred name analysis: Children with a lower verbal age were more likely to produce preferred names overall, and more likely to produce a preferred name after hearing a preferred than a dispreferred name. This pattern is consistent with Branigan et al. (2016).

Likelihood of aligning on either name: ASD vs. typically-developing supergroups (Table 10)

A final analysis compared how ASD and typically-developing supergroups (chronological-age-matched; verbal-age-matched) differed in their overall tendency to align. Fixed effects were group, prime name, and a group:prime name interaction. We also included verbal age as a fixed effect, in case this mediated any group differences in alignment. There was a significant effect of prime name, but no effect of verbal age, and no interactions of group or prime name with verbal age. Importantly, the contrasts for the chronological-age-matched and verbal-age-matched supergroups were not significant, consistent with analyses of individual experiments. That is, a large sample of children with ASD did not differ significantly from large samples of chronological age-matched and verbal-age-matched children in the extent to which they aligned with the experimenter.

General Discussion

Children with ASD display pragmatic deficits during interaction. Competing accounts attribute these deficits to theory of mind impairments or constraints affecting online use of communicative perspective-taking, including executive functioning. We investigated whether conflict inhibition, which regulates speakers' ability to accommodate others' perspectives, is implicated in children with ASD's referential communication. Our study focused on lexical alignment, which can be mediated by communicative perspective-taking in typical adults.

Across two experiments, children with ASD showed a robust tendency to spontaneously repeat their interlocutor's referential choices, in the same way and to the same extent as typically-developing children. This lexical alignment occurred whether their interlocutor had used a preferred or dispreferred name for an object, and was unaffected by chronological age and verbal age. More critically, we found no relationship between children with ASD and typically-developing children's lexical alignment and conflict inhibition. Children with ASD's alignment was also unrelated to their theory of mind, and to ASD symptom severity (i.e., SCQ scores).

Our results provide further evidence that children with ASD's referential communication is not uniformly aberrant (Branigan et al., 2016). Specifically, they demonstrate that an aspect of referential communication associated with successful and fulfilling interaction in adult dialogue is intact under at least some circumstances. They imply that conversational difficulties in ASD do not stem from a general deficit in linguistic imitation (Charman et al., 2000). They also suggest that conflict inhibition impairments do not adversely affect all aspects of children with ASD's referential communication. When children with ASD showed poorer conflict inhibition than typically-developing controls, they aligned to the same extent; individual differences in conflict inhibition did not affect alignment.

These experiments therefore imply that aspects of children with ASD's referential communication are robust against deficits in conflict inhibition, under some circumstances. These findings are consistent with accounts attributing children with ASD's pragmatic deficits to contextually-contingent processing limitations, rather than limitations in underlying competence (Nilsen & Fecica, 2011). In our study, results suggest that children with ASD and typically-developing children's lexical alignment was not driven by communicative perspective-taking. Rather, priming appears a likely explanation for the pattern of their responses. Lexical priming mechanisms, which automatically facilitate the use of a partner's previous referential choice, may be sufficient to yield successful communication in many contexts (Pickering & Garrod, 2004), such as the highly-structured context of our game.

Priming mechanisms may therefore be one component of how such contexts support communication in individuals with ASD (Begeer, Malle, Nieuwland, & Keysar, 2010). However, this carries clinical implications: assessments of communication skills in children with ASD (e.g., the ADOS) usually involve semi- or highly-structured interactions; our results suggest that these may not adequately capture the nature of children with ASD's conversational difficulties. Specifically, our study shows that an adult partner's language can scaffold and 'normalise' children with ASD's use of referring expressions, potentially obscuring the extent of a child's pragmatic impairment.

Furthermore, communicative perspective-taking could be critical to alignment in other interactive contexts, for example when potential miscommunication costs and/or differences in perspective are salient (e.g., with a less capable partner; Branigan et al., 2011), and when speakers have sufficient time and resources to engage in perspective-taking (Epley, Morewedge, & Keysar, 2004; Nadig & Sedivy, 2002). Accordingly, we suggest that although susceptibility to priming may facilitate conversation for children with ASD in a highly-structured context, such 'primeability' could represent a liability when it occurs alongside impaired communicative perspective-taking.

One reason for this is that speakers with impaired perspective-taking may be too easily satisfied that surface-level alignment (here, using the same word) indicates deeper-level, conceptual coordination. Another possibility is their being less likely to be able to 'diverge' (i.e., resist the tendency to align) when necessary. Garrod and Clark (1993) demonstrated that younger typically-developing children are prone to such pitfalls: 7-8-year-olds succumbed to lexical priming that was communicatively maladaptive (because the same word connoted different referents), whereas older children (9-10 and 11-12 years) directly negotiated a common lexicon when communication breakdown occurred. Preliminary evidence suggests that children with ASD experience the same 'double jeopardy' when conversing with a typically-developing peer, compared with groups of chronological-age-matched and verbal-age-matched typically-developing children (Hopkins et al., under revision).

Hence a further clinical implication of our study is that children with ASD's susceptibility to priming may create additional pragmatic challenges in more complex, communicatively demanding situations. Such situations may offer potential sites for identifying differences between children with ASD and typically-developing children's lexical alignment, and more generally for demonstrating a relationship between conflict inhibition and communicative perspective-taking.

We conclude that one important aspect of referential communication is robust to impairments in conflict inhibition and theory of mind in children with ASD, under some circumstances. These results provide further evidence that children with ASD's pragmatic deficits may be complex, and help clarify the conditions under which they may be ameliorated or exacerbated.

Key points:

- Typical adults' *lexical alignment* implicates communicative perspective-taking, regulated by conflict inhibition and theory of mind.
- We found that children with ASD show lexical alignment, to the same extent as chronological- and verbal-age-matched typical children, despite conflict inhibition/theory of mind deficits.
- We found no relationship between conflict inhibition/theory of mind and alignment in children with ASD, suggesting alignment arose from priming mechanisms.
- Our findings suggest that in structured interactions, children with ASD's referential communication is robust to conflict inhibition/theory of mind deficits.
- We caution that, while priming may support children with ASD's language during conversation, it could also cause pragmatic difficulties in communicatively demanding situations.

Notes

[1] While studies of alignment typically focus on speakers' use of dispreferred choices, we also examined preferred name alignment, because children with ASD show unusual lexical choices in natural conversation, and so would not necessarily use 'preferred' names by default.

Acknowledgements

We thank participating schools, Rebecca Donne, and Alessia Tosi. This research was supported by an EPSRC (EP/K503198/1) and an ESRC (ES/N013115/1) grant.

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Table 1: Participant characteristics: Mean (range) verbal age and chronological age (in years.months)

Experiment	Group	*N*	Chronological age	Verbal age
1	ASD	12	10.8	9.6
			(8.2–12.5)	(6.7–12.6)
	Chronological match	12	10.3	11.4
			(7.9–11.8)	(9.2–12.6)
	Verbal match	12	9.3	9.9
			(6.6–11.8)	(7.9–12.8)
2	ASD	14	12.6	7.4
			(10.3–15.8)	(2.6–12.4)
	Chronological match	14	12.6	13.1
			(10.0–15.5)	(11.4–13.6)
	Verbal match	14	5.7	7.5
			(3.1–13.7)	(2.9–12.3)

Figure 1: Example game trial (dispreferred-name condition; adapted from Branigan et al., 2016)

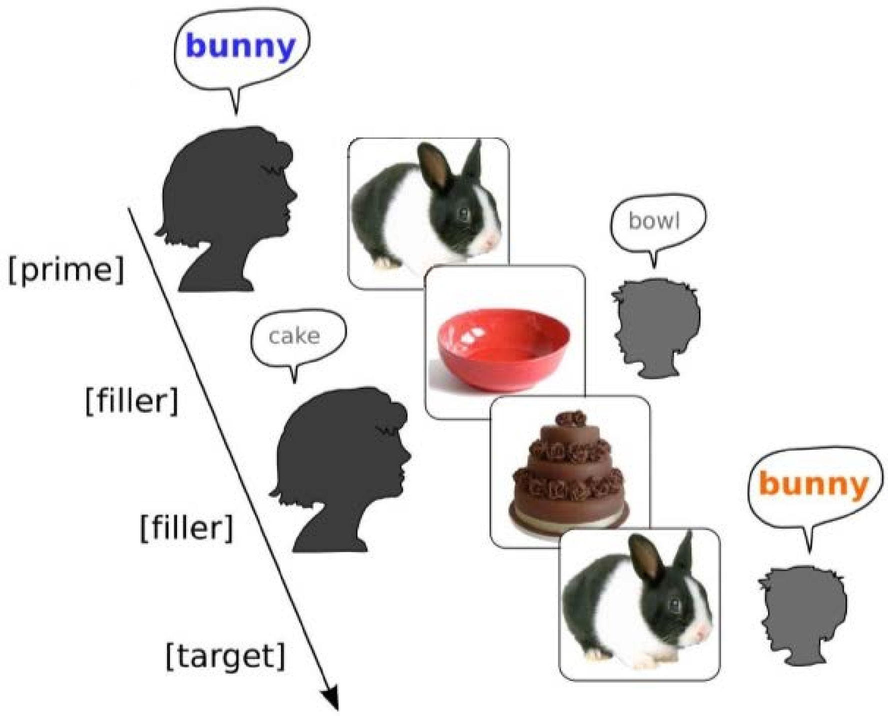

Table 2: Frequency (and percentage) of responses

			Prime name		
Experiment	**Group**	**Response**	**Preferred**	**Dispreferred**	**Alignment effect†**
1	ASD	Preferred	101 (84%)	28 (23%)	61%
		Dispreferred	9 (8%)	86 (72%)	64%
		Other	10 (8%)	6 (5%)	
	Chronological match	Preferred	110 (92%)	21 (18%)	74%
		Dispreferred	1 (1%)	96 (80%)	79%
		Other	9 (8%)	3 (3%)	
	Verbal match	Preferred	111 (93%)	25 (21%)	72%
		Dispreferred	3 (3%)	90 (75%)	73%
		Other	6 (5%)	5 (5%)	
2	ASD	Preferred	124 (89%)	42 (30%)	59%
		Dispreferred	4 (3%)	84 (60%)	57%
		Other	12 (9%)	14 (10%)	
	Chronological match	Preferred	125 (89%)	29 (21%)	69%
		Dispreferred	8 (6%)	105 (75%)	69%
		Other	7 (5%)	6 (4%)	
	Verbal match	Preferred	131 (94%)	42 (30%)	64%
		Dispreferred	5 (4%)	91 (65%)	61%
		Other	4 (3%)	7 (5%)	

† Increased probability (%) of producing an aligned name (i.e., dispreferred target after dispreferred prime compared with after preferred prime; and preferred target after preferred prime compared with after dispreferred prime).

Table 3: Experiment 1: LME model summaries: likelihood of aligning on preferred names in the ASD and typically-developing groups

	ASD group				**Typically-developing group**			
	Parameter estimates		**Wald's test**		**Parameter estimates**		**Wald's test**	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	0.09	0.47	0.21		0.59	0.51	1.16	
Prime name	-4.23	0.92	-4.58	<.001	-6.56	1.02	-6.41	<.001
Junior Hayling score	-0.01	0.26	-0.03	>.1	-0.17	0.23	-0.71	>.1
Prime name:junior Hayling score	0.04	0.74	0.06	>.1	-1.35	0.91	-1.49	>.1

Table 4: Experiment 1: LME model summaries: likelihood of aligning on dispreferred names in the ASD and typically-developing groups

	ASD group				**Typically-developing group**			
	Parameter estimates		**Wald's test**		**Parameter estimates**		**Wald's test**	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	-0.80	0.49	-1.62		-2.23	1.50	-1.49	
Prime name	4.53	0.88	5.14	<.001	8.81	3.07	2.87	<.01
Junior Hayling score	-0.32	0.42	-0.76	>.1	0.34	0.48	0.71	>.1
Prime name:junior Hayling score	0.83	0.80	1.03	>.1	1.08	1.04	1.03	>.1

Table 5: Experiment 2: LME model summaries: likelihood of aligning on preferred names in the ASD and typically-developing groups

	ASD group				**Typically-developing group**			
	Parameter estimates		**Wald's test**		**Parameter estimates**		**Wald's test**	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	0.83	0.29	2.84		0.81	0.27	3.01	
Prime name	-3.62	0.67	-5.44	<.001	-4.31	0.50	-8.54	<.001
Day-night score	-0.17	0.30	-0.58	>.1	0.03	0.17	0.20	>.1
Prime name:day-night score	-0.01	0.70	-0.20	>.1	-0.24	0.43	-0.57	>.1

Table 6: Experiment 2: LME model summaries: likelihood of aligning on dispreferred names in the ASD and typically-developing groups

	ASD group†				**Typically-developing group†**			
	Parameter estimates		**Wald's test**		**Parameter estimates**		**Wald's test**	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	-1.67	0.33	-5.06		-1.40	0.29	-4.70	
Prime name	4.28	0.76	5.61	<.001	4.98	0.64	7.78	<.001
Day-night score	-0.03	0.29	-0.11	>.1	0.19	0.23	0.86	>.1
Prime name:day-night score	0.35	0.64	0.55	>.1	-0.10	0.58	-0.17	>.1

† Converged upon simplifying random effects.

Table 7: summary of LME models: likelihood of aligning on either name[1]

Experiment	**Predictors**	**Parameter estimates**		**Wald's test**	
		β	**S.E.**	**z**	**p(β=0)**
1	Intercept	1.66	0.41	4.07	
	Prime name	-0.90	0.35	-2.61	<.01
	ASD-chronological match	0.92	0.57	1.62	>.1
	ASD-verbal match	0.55	0.56	0.99	>.1
	Prime name:ASD-chronological match	-3.44	0.57	-0.61	>.1
	Prime name:ASD-verbal match	-0.75	0.55	-1.37	>.1
2†	Intercept	1.53	0.31	4.93	

Prime name	-1.94	0.47	-4.14	<.001
ASD-chronological match	0.60	0.45	1.33	>.1
ASD-verbal match	0.40	0.43	0.93	>.1
Prime name:ASD-chronological match	0.36	0.79	0.84	>.1
Prime name:ASD-verbal match	-0.45	0.56	-0.81	>.1

† Converged upon simplifying random effects.

Table 8: ASD supergroup: LME model summaries: likelihood of aligning on preferred or dispreferred names

	Production of preferred responses†				Production of dispreferred responses†			
	Parameter estimates		Wald's test		Parameter estimates		Wald's test	
	β	**S.E.**	**z**	**p(β=0)**	**β**	**S.E.**	**z**	**p(β=0)**
Intercept	0.58	0.25	2.32		-2.33	0.50	-4.68	
Prime name	-3.05	0.59	-5.18	<.001	5.68	1.30	4.37	<.001
Theory of mind	-0.11	0.28	-0.41	>.1	0.02	0.47	0.05	>.1
Verbal age	0.13	0.25	0.52	>.1	0.54	0.51	1.06	>.1
Chronological age	0.14	0.19	0.74	>.1	0.42	0.39	1.06	>.1
SCQ	0.22	0.18	1.19	>.1	0.20	0.32	0.63	>.1
Prime name:theory of mind	-0.15	0.79	-0.19	>.1	-0.16	1.30	-0.12	>.1
Prime name:verbal age	-0.55	0.76	-0.73	>.1	0.30	1.35	0.22	>.1
Prime name:chronological age	-0.53	0.59	-0.91	>.1	-0.99	1.07	-0.92	>.1
Prime name: SCQ	-0.15	0.55	-0.26	>.1	-0.58	0.90	-0.64	>.1

† Converged upon simplifying random effects.

Table 9: Typically-developing supergroup: LME model summaries: likelihood of aligning on preferred name or dispreferred names

	Production of preferred responses				Production of dispreferred responses†			
	Parameter estimates		Wald's test		Parameter estimates		Wald's test	
	β	S.E.	z	p(β=0)	β	S.E.	z	p(β=0)
Intercept	0.87	0.32	2.68		-1.59	0.30	-5.35	
Prime name	-5.65	0.61	-9.31	<.001	6.07	0.63	9.62	<.001
Theory of mind	0.09	0.20	0.43	>.1	-0.13	0.28	-0.44	>.1
Verbal age	-0.60	0.31	-1.94	=.05	0.64	0.42	1.54	>.1
Chronological age	0.20	0.28	0.72	>.1	-0.13	0.37	-0.36	>.1
Prime name:theory of mind	0.62	0.62	1.01	>.1	-0.50	0.71	-0.70	>.1
Prime name:verbal age	-1.67	0.96	-1.73	=.08	1.56	1.08	1.44	>.1
Prime name:chronological age	1.34	0.96	1.40	>.1	-1.61	1.02	-1.57	>.1

† Converged upon simplifying random effects.

Table 10: All children supergroup: LME model summaries: likelihood of aligning on either name

	Production of aligned responses			
	Parameter estimates		**Wald's test**	
	β	**S.E.**	**z**	**p(β=0)**
Intercept	1.76	0.28	2.65	
Prime name	-1.28	0.46	-9.23	<.01
ASD-chronological match	1.19	0.75	0.52	>.1
ASD-verbal match	0.51	0.40	-2.03	>.1
Verbal age	0.30	0.24	1.23	>.1
Prime name:ASD-chronological match	-0.33	0.90	-0.37	>.1
Prime name:ASD-verbal match	-0.80	0.47	-1.70	>.1
Prime name:verbal age	0.29	0.27	1.08	>.1
ASD-chronological match:verbal age	-0.91	0.75	-1.20	>.1
ASD-verbal match:verbal age	-0.15	0.36	-0.41	>.1
Prime name:ASD-chronological match:verbal age	-0.26	0.92	-0.28	>.1
Prime name:ASD-verbal match:verbal age	0.12	0.43	0.27	>.1